Iron and Manganese as proxies for oxygenation and diagenesis in foraminifera

E. Brendan Roark[1], B. Lynn Ingram[1,2], and Geraldine Lamble[3]

[1]Department of Geography, University of California, Berkeley, California 94720, USA
[2]Department of Geology and Geophysics, University of California, Berkeley, California 94720, USA
[3]Advanced Light Source, Ernest Orlando Lawrence Berkeley National Laboratory, University of California, Berkeley, California 94720, USA

During the late Quaternary, ocean conditions in Santa Barbara Basin (SBB) switched between two primary states: 1. Laminated or varved sediments, which formed during periods of low oxygen and contain low-oxygen tolerant benthic foraminifera; and 2. massive bioturbated sediments, representing periods of greater oxygenation in the basin, and which contain foraminifera preferring higher oxygen conditions. Laminated sediments occur as a result of suboxic (<0.1mL/L oxygen) bottom waters in the basin below ~475 m, combined with highly productive surface waters that generate abundant organic material, consuming the small supply of oxygen that enters the basin (Kennett, et al., 1994). Using the degree to which these sediments were laminated, Behl and Kennett, (1996) assigned a bioturbation index ranging from 1 to 4. A bioturbation index of 1 was associated with varved sediments in which benthic oxygenation was <0.1 ml O_2 per liter while a bioturbation index of 4 indicated the oxygenation was >0.3 ml O_2 per liter.

In most marine sediments the interstitial fluids are derived from the sea water in the overlying water column. This interstitial complex of sediments, rocks, and water is the site of numerous physical , biological, and chemical reactions that can change both the mineral phases and the composition of the water. These changes are commonly grouped together under the term diagenesis. In early diagenesis most of the chemical changes that occur are dependent on the redox environment which is in turn controlled by the amount of organic carbon undergoing decomposition or preservation. This process of oxidation is a result of catabolic microbial reactions that break down organic molecules into simple molecules or inorganic elements. Further more there is a diagenetic sequence of the catabolic processes which is dependent on which oxidizing agent is consuming the organic carbon. Oxygen is the preferred electron acceptor as the organic matter is metabolized and donates electrons to the oxidizing components. However, if there is no oxygen present a succession of secondary oxidants will be used. The two most common of which are Manganese (Mn) and Iron (Fe). In the case of iron, Fe^{3+} undergoes reduction to Fe^{2+} as is shown in the equation below where (C) represents organic matter:

$$4\ Fe^{3+}\ \ (C)\ + 2H_2O \rightarrow 4\ Fe^{2+}\ \ CO_2 + 4\ H^+$$

The purpose of this study is to develop a technique by which Fe^{3+} and Fe^{2+} can be measured in benthic foraminifera from Santa Barbara Basin so that we can use the results as a proxy for the oxygen content of the basin. As a result of diagenesis, Fe and Mn coatings can be found on foraminifera. Preliminary results of X-Y scans on several foraminifera from anoxic layers in SBB show that these coatings do contain relatively high levels of Fe. MicroXANES scans on the regions of high Fe concentration were also conducted. Representative results from one such scan are shown in Figure 1. Figure 1 shows an Fe microXANES spectrum from a foraminifera alongside an Fe^2O^3 microXANES spectrum from a Fe^2O^3 standard. Clearly the Fe in the foraminifera is at the lower oxidation state of Fe^2 which would be indicative of a reducing environment which we would expect from the low oxygen content of the sediments from which the foraminifera came. In on going work we continue to look for relative changes in the levels and speciation of the Fe and Mn in the diagenetic coatings of the foraminifera. We expect to see variations in these results based on the oxygen content of sediments from which the foraminifera come.

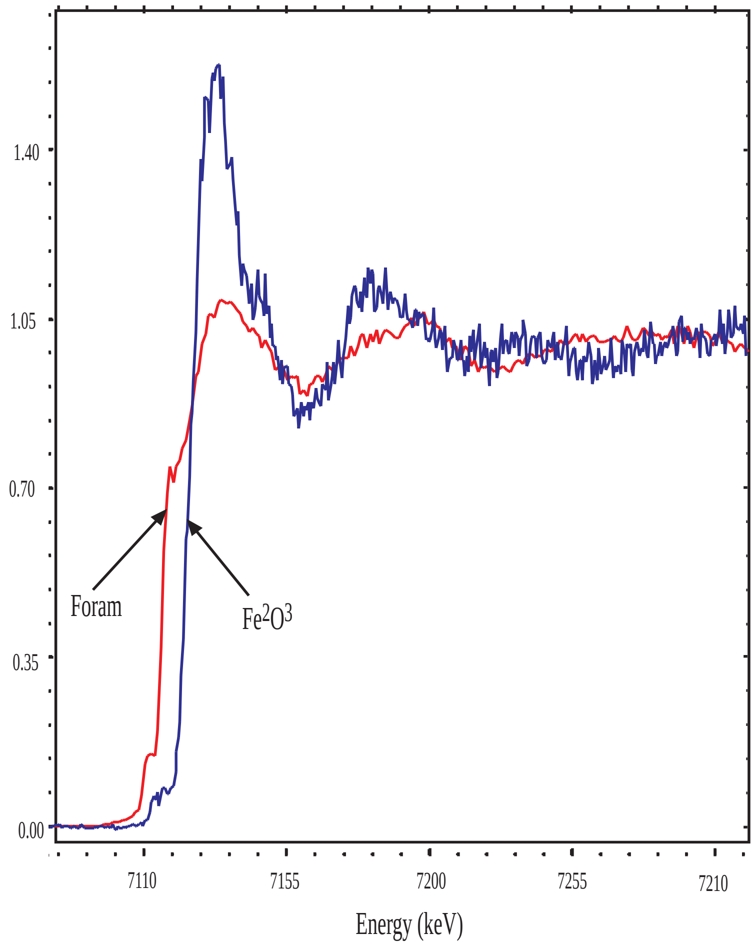

Figure 1: MicroXANES scans of Fe^2 coating of a foraminifera from anoxic bottom water conditions in Santa Barbara Basin and a MicroXANES scan of an Fe^2O^3 standard.

REFERENCES

Behl, R.J., and Kennett, J.P., Brief interstadial events in the Santa Barbara Basin, NE Pacific, during the past 60 kyrs, Nature 379, 1996.

Kennett, J.P., Baldauf, J.G. et al., Proceedings of the Ocean Drilling Program Initial Reports, 146, Part 2: Santa Barbara Basin, 81 pp, Ocean Drilling Program, College Station, Texas, 1994.

This work was supported by the Office of Energy Research, Office of Basic Energy Sciences, Materials Sciences Division, of the U.S. Department of Energy under Contract No. DE-AC03-76SF00098 at Lawrence Berkeley National Laboratory.

Principal investigator: E. Brendan Roark Department of Geography, University of California, Berkeley. Email ebroark@socrates.berkeley.edu. Telephone: 510-643-8353.